(72) Inventor : Eisenbarth, Christoph
P.O. Box 581
El Granada, CA 94018 (US)
Inventor : Finkelstein, Ira
985 Taji Ct
San José, CA 95122 (US)
Inventor : McGhie, Dennis
150 Mimosa Way
Portola Valley, CA 94028 (US)
Inventor : Panofsky, Edward
Star Route 159B
Woodside, CA 94062 (US)

(74) Representative : Jörchel, Dietrich R.A. et al
c/o BUGNION S.A. Case postale 375
CH-1211 Genève 12 - Champel (CH)

(54) Method and apparatus for determining mis-registration.

(57)   An image processing apparatus includes a
data acquisition stage for acquiring data rep-
resentative of several spatially separated reg-
ions of a sample. The apparatus also includes
data storage means for storing reference data
corresponding to the sample data. The two sets
of data are compiled and analyzed to determine
if the sample is shifted from a nominal position.

FIG. 1

EP 0 582 548 A1

This invention relates to an electronic image processing device which uses automatic image registration techniques and equipment for assuring valid registration of the images and more particularly to an apparatus in which several regions are used for the comparison.

Many image processing steps require two or more images to be mutually aligned, based on the content of the images. Several methods exist to determine the amount of mis-registration, and to utilize the detected mis-registration to re-register images for further processing. The simplest re-registration technique is to shift the image data of one or more images to align with a single reference image. The amount of shift used is detected by the quantitative mis-registration detection.

Quantitative mis-registration detection methods currently in use include edge recognition, point recognition, correlation of row and column sums, correlation of local regions and others. These methods are useful in many situations, but have limitations due to accuracy, computation complexity, and limited application in certain image situations.

Another quantitative mis-registration detection method performs a comparison of a test image local region with a reference image local region by summing the absolute value of the difference of the two local regions, on a pixel-by-pixel basis. One of the two local regions is then shifted along the X axis by one pixel and the summation performed again. This operation is repeated a number of times and the summation result recorded for each position. The X axis shift amount is then returned to the original point and the region is shifted along the Y axis by one pixel. The X axis shifting and summation is then repeated for this new Y axis position. This Y axis shifting, and subsequent X axis shifting and summing is repeated a number of times. The recorded summation results are then examined and the minimum value noted. The minimum summation result corresponds to the pixel shift that best aligns the features within the local region.

The amount of shifting is determined by the expected maximum mis-registration amount, and is centered about the nominal position. The size and position of the local region is selected to include an image feature which has significant contrast and non-repeating information content in both the horizontal and vertical directions.

This mis-registration detection method is similar in operation to unnormalized correlation of local regions, but requires much simpler computations as no multiplications are needed.

It is an object of the invention to provide method and means to detect mis-registration of test images with respect to a reference image.

Another objective of the present invention is to provide a method and apparatus which may readily be adapted to several misalignment detection processes.

A limitation of the unnormalized correlation of local regions and the minimum of sums of absolute differences of local regions methods is that, for real world objects, there may not be a local region with sufficient contrast and non-repeating information content in both the horizontal and vertical directions. In the present invention local region comparison is performed using two or more local regions from a reference image and two or more local regions from the test image. The local regions are selected to include approximately orthogonal information content in the two local regions. The information in the two local regions is spatially linked, but may be widely separated within the image frame. To use this concept with the sum of absolute differences method, a summation of the absolute value of the difference of one of the local regions in the reference image and the corresponding local region in the test image, on a pixel-by-pixel basis is performed. Then the sum of the absolute differences of the other local region in the reference image and the corresponding local region in the test image is performed. These two sums are then added to each other and the result recorded. The two local regions in the reference image are then shifted along the X axis by one pixel with respect to the test image and the two summations and final sum performed again. This operation is repeated a number of times and the sum of summations recorded for each position. The X axis shift amount is then returned to the original point and the regions are shifted along the Y axis by one pixel. The X axis shifting and sum of summations is then repeated for this new Y axis position. This Y axis shifting, and subsequent X axis shifting and summing is repeated a number of times. The minimum sum of summations result corresponds to the pixel shift that best aligns the features within the two local regions.

The concept of using two local regions from a reference image to compare against two local regions from a test image can be extended to the unnormalized correlation of local regions method of mis-registration determination. The operation is the same as the previously described two region minimum of sums of absolute differences method, except that a sum of products is performed at each X and Y axis shift position for each local region, the sums added, and the result recorded. When all shifts have been completed, the recorded results are examined and the maximum value corresponds to the pixel shift that best aligns the features within the two local regions.

The concept of using two local regions from a reference image to compare against two local regions from a test image using correlation, minimum of sums of the absolute differences, or other comparison method, can be extended to use any number of local regions from a reference image to compare against

the same number of local regions from a reference al-
lows including multiple spatially linked features in the
comparison, thus ensuring a robust mis-registration
determination.

    Figure 1 shows an image acquisition system con-
structed in accordance with this invention;
    Figure 2 shows an object being scanned by the
system of Figure 1;
    Figure 3 shows several local regions of a refer-
ence region; and
    Figure 4 shows the elements of the image proc-
essor of the system of Figure 1.

    The image acquisition system disclosed herein is
particularly suited for an apparatus for checking print-
ed patterns. The system 10 may include for example
a rotating drum 12 which carries a sheet 14 past a
scanner 16. Sheet 14 may be imprinted with a plural-
ity of printed patterns arranged in a rectangular array.

    Scanner 16 is used to scan sheet 14 to produce
an image of thereof for image acquisition means 18.
The image of the sheet 14, or at least portions of the
sheet are loaded in a digital form from means 18 to a
memory 20.

    Apparatus 10 also includes another memory 22,
used to store the image of a reference sheet. The two
images from memories 20 and 22 are provided to an
image processor 24 which is used to determine if the
image from scanner 16 has been shifted in one or
both orthogonal directions.

    Figure 2 shows a printed pattern banknote 26
from sheet 14 bearing an image 28. In order to deter-
mine whether the image 28 has been shifted, three
local areas 30, 32, 34 are selected and analyzed as
follows. The three local areas may be chosen arbitrar-
ily, however preferably they are selected to contain
prominent features extending either in one of two or-
thogonal directions X or Y. For the purposes of this
discussion an image 28 is assumed to have been pro-
duced from a single plate, for example by offset print-
ing. Frequently, the a printed pattern is printed with
several superimposed images, each image being
generated by a different printing method. In such sit-
uations, the steps presented here are repeated for
each image so that the orthogonal shift of each im-
age may be determined.

    Each local image area 30, 32, 34 preferably com-
prises a two dimensional array of pixels. Memory 22
may contain either a complete reference image, or lo-
cal areas of the reference image corresponding to
the local areas 30, 32, 34. These local reference
areas are illustrated in Figure 3 by three pixel arrays
30', 32', 34'. Advantageously each pixel of the local
arrays may be represented as a two dimensional co-
ordinate. For example, the pixel at the upper left hand
corner of arrays 30', 32', 34' can be referred to as pix-
els A11', B11' and C11' respectively. Originally, it is
assumed that the local areas of the actual image 28
coincide exactly with the local areas of the reference

image. In other words, it is assumed that center pixel
of region 30' (shaded in Figure 3) coincides with the
center pixel of region 30.

    As shown in more detail in Figure 4, the image
processor 24 includes five counters 40, 42, 44, 46, 48,
a summer network 50, a memory 52, a comparator 54
and a shift selector 56. It should be understood that
the image processor of Figure 4 is preferably imple-
mented as a digital computer and the components
shown in the Figure are shown for illustrative purpos-
es.

    In order to determine if the actual image from
memory 20 is shifted orthogonally with respect to the
reference image of memory 22, a reiterative process
is performed as follows. Counter 40 sequentially des-
ignates one of the local regions 30', 32' 34' of the ref-
erence image to the summer network 50. Initially
counters 42, 44 are set to zero indicating that no shift
has yet occurred. Counters 46 and 48 are used as
pointers to indicate to the network 50 which pixel of
an array is to be processed. After the counter 40 des-
ignates the first local region 30', the summer network
50 obtains the values of each pixel of region 30 and
takes the absolute value of the difference of the value
of each pixel of array 30 and array 30'. Thus, the sum-
ming network 50 calculates the differences $|A11-
A11'|$, $|A12-A12'|$ and so on. These differences are
summed and stored. The first position of a results ar-
ray in memory 52 and in a "best match" location also
in memory 52. When the differences for all the pixels
of arrays 30 and 30' have been calculated and stored,
counter 40 is incremented and the whole process is
repeated for arrays 32, 32', with the difference from
each pixel being summed with the difference of the
calculation for the same position for arrays 30, 30'. In
other words, for the second set of arrays 32, 32', the
summing network 50 first obtains the difference B11-
B11' and adds this difference to the difference A11-
A11'. The same process is repeated for each of the
other pixels of arrays 32, 32' under the direction of
counters 46, 48. Finally, the same process is again re-
peated for the third set of arrays 34, 34'. Once the cal-
culations are completed, counter 42 is incremented
by one to indicate that the reference arrays 30',
32' and 34' must be offset along the x-axis by one pix-
el. The summer network 50 again performs the
above-described process, but this time the pixels of
the reference image are offset so that for example the
difference A12-A11' is calculated and stored tempor-
arily until the calculations for all the three sets of ar-
rays are completed. Comparator 54 then compares
the resulting value with the value resulting with no
shift. This value is placed in the second position in the
results array in memory 52. If the new results meet
certain criteria (i.e. they are equal to or smaller than
the old results) the old value in the best match loca-
tion in memory 52 is replaced with the new ones. If
the results are replaced, the shifts in the X and Y di-

rection as indicated by counters 42, 44 are also stored in memory 52. The arrays 30' 32' 34' are then shifted again and the whole process is repeated. The three arrays 30' 32' 34' are shifted a predetermined number of times to the left and right of the original position. Thereafter, the arrays are also shifted up and down a preselected number of times.

When all the shifts and calculations are completed, memory 52 contains the results array shoving the values due to the orthogonal shiftings, and the best match value and the amount of shift in the X and Y direction which generated this result. This information is provided to shift selector 56 which generates a corresponding X- and Y- shift indicating the orthogonal offset of image 28 from a reference image. The results array of summations in memory 52 may be used as a quantitative measure which may be used to determine the level of confidence in the process.

In the embodiment described above, three local areas are used for illustrative purposes. It should be understood that any number of such areas may be used higher than one. Moreover, other criteria for comparing the image and reference arrays without departing from the scope of the invention as defined in the appended claims.

Claims

1. An image processing apparatus comprising:
    image acquisition means for acquiring data corresponding to an image, said image including several spatially separated local regions;
    storage means for storing reference information; and
    compiling means for compiling information from said local regions and said reference information;
    analyzing means for analyzing the compiled information to determine if said image is shifted from a nominal position.

2. The apparatus of claim 1 wherein said information from said local regions and said reference information are arranged in a two dimensional array of pixels.

3. The apparatus of claim 2 further comprising shifting means for shifting information from said local regions selectively in one of two orthogonal directions.

4. An image processing apparatus comprising:
    image acquisition means for acquiring data from several local regions of a sample, said data being partitioned into corresponding sample arrays of pixels;
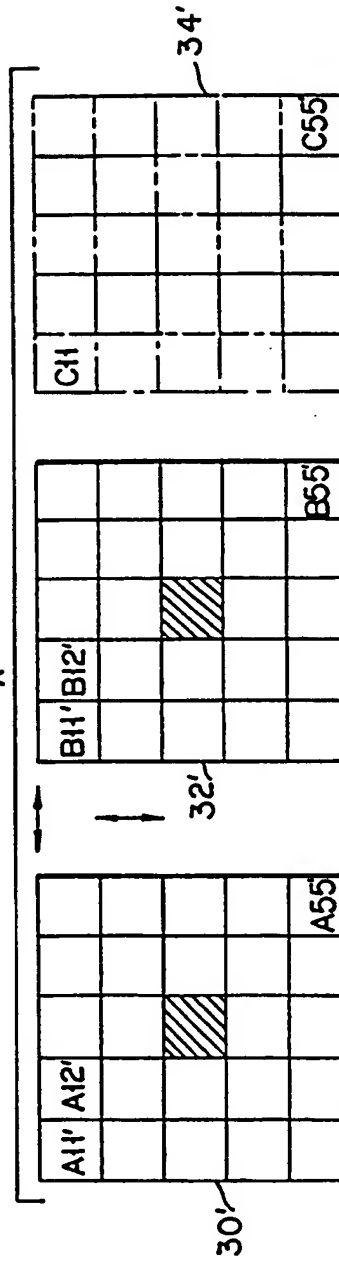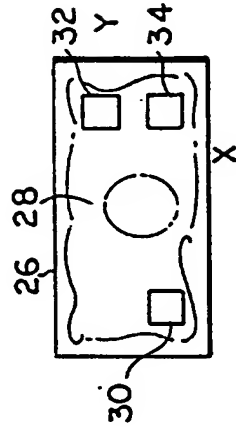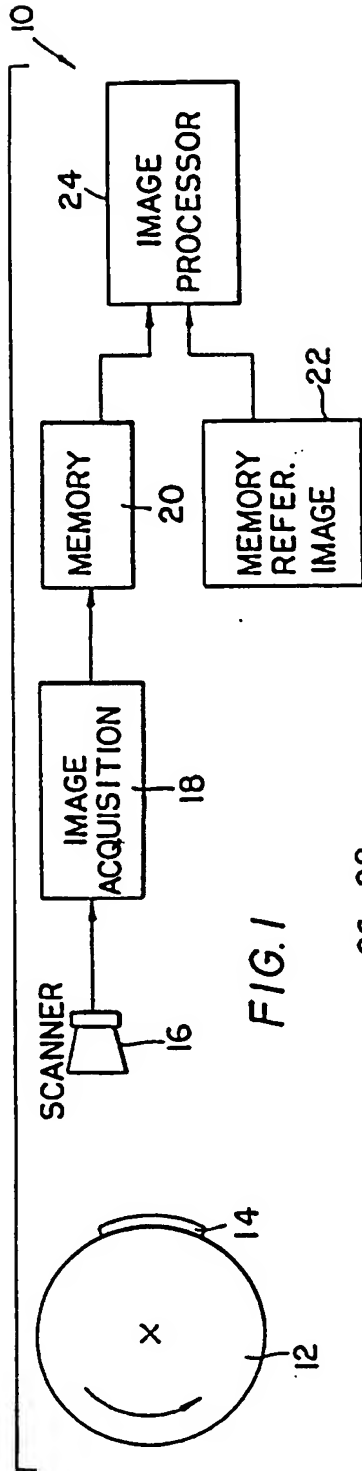   memory means for storing several refer-

ence arrays of pixels;
    comparing means for comparing said sample and said reference arrays;
    compiling means for compiling the results of the comparison; and
    analyzing means for determining shifts between said sample and reference arrays.

5. The system of claim 4 wherein said apparatus further includes shifting means for shifting one of said references arrays and said sample arrays in a predetermined direction.

6. A method of determining a linear shift of a sample from a nominal position comprising the steps of:
    acquiring image data arranged in several sample arrays of pixels, each array corresponding to a local region of said sample;
    comparing said sample arrays to corresponding reference arrays;
    storing a difference array corresponding to the difference of said sample and reference arrays;
    shifting said sample arrays; and
    comparing the difference between said shifted sample arrays and said reference arrays to said stored difference.

7. The method of claim 6 wherein said sample and reference arrays are analyzed on a pixel-by-pixel basis.
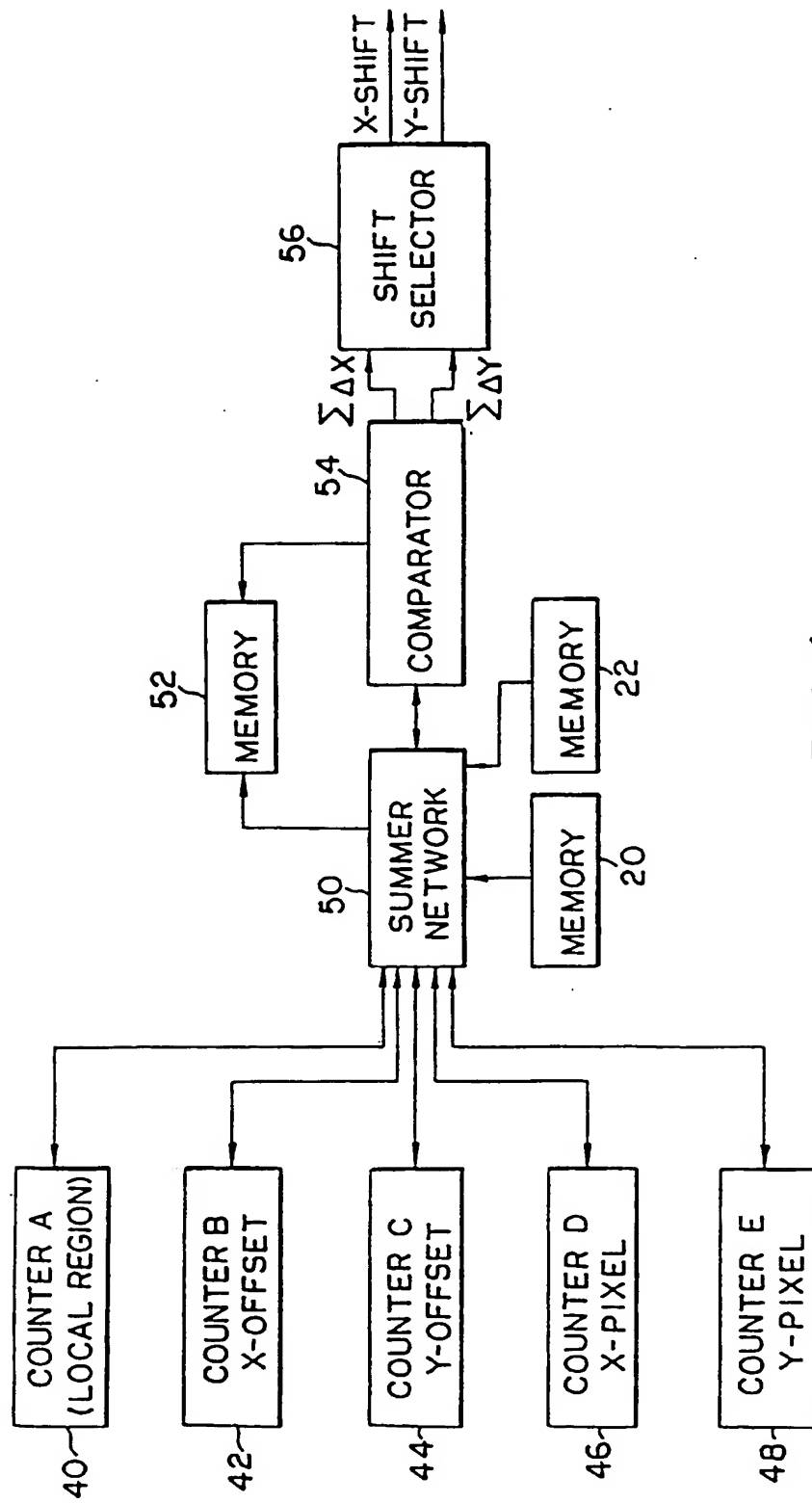
FIG. 1

FIG. 2

FIG. 3

REF. IMAGE REGION #1

REF. IMAGE REGION #2

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP   93 81 0534

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 440 137 (EZEL INC.) 7 August 1991 * abstract; figures 1,2,5-8 * * page 3, line 10 - page 9, line 5 * ---	1-7	H04N1/00
X	PATENT ABSTRACTS OF JAPAN vol. 7, no. 133 (M-221)10 June 1983 & JP-A-58 049 262 (DAINIPPON INSATSU KK) 23 March 1983	1,4	
A	* abstract * ---	2,3,5-7	
A	EP-A-0 449 336 (DAINIPPON SCREEN MFG. CO.) 2 October 1991 * abstract; figures 1-3 * * column 4, line 3 - column 8, line 52 * ---	1-7	
A	EP-A-0 485 051 (INTERNATIONAL COMPUTERS LIMITED) 13 May 1992 * abstract; figures 1-3 * * column 1, line 54 - column 2, line 56 * ---	1-7	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	US-A-5 086 486 (YAMADA) 4 February 1992 * abstract; figures 2,3 * * column 2, line 29 - column 3, line 35 * ---	1,4,6	H04N
A	EP-A-0 197 734 (RANK CINTEL LIMITED) 15 October 1986 * abstract; figures 4,5 * * page 5, line 28 - page 7, line 1 * -----	1,4,6	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 OCTOBER 1993	MACHWIRTH C.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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